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In re Patent Application of	)	
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Jonas PERSSON	)	Group Art Unit: 2614
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Application No.: 09/977,193	)	Examiner: Unassigned
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Filed: October 16, 2001	)	
	)	
For: COMMUNICATIONS SYSTEMS	)	

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Sir:

The benefit of the filing date of the following prior foreign application in the following foreign country is hereby requested, and the right of priority provided in 35 U.S.C. § 119 is hereby claimed:

United Kingdom Patent Application No. 0025436.7

Filed: October 17, 2000

In support of this claim, enclosed is a certified copy of said prior foreign application. Said prior foreign application was referred to in the oath or declaration. Acknowledgment of receipt of the certified copy is requested.

Respectfully submitted,

BURNS, DOANE, SWECKER & MATHIS, L.L.P.

Date: February 6, 2002

By: [signature]
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1. Your reference	HL76381/000/CIV	18OCT00 E576619-10 D02847 P01/7700 0.00-0025436.7
2. Patent application number *(The Patent Office will fill in this part)*	**0025436.7**	17 OCT 2000
3. Full name, address and postcode of the or of each applicant *(underline all surnames)*	TELEFONAKTIEBOLAGET L M ERICSSON (PUBL) SE-126-25 STOCKHOLM SWEDEN	
Patents ADP number *(if you know it)*		784406100l
If the applicant is a corporate body, give the country/state of its incorporation	SWEDEN	
4. Title of the invention COMMUNICATIONS SYSTEMS		
5. Full name of your agent *(if you have one)*	Haseltine Lake & Co.	
"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*	Imperial House 15-19 Kingsway London WC2B 6UD	
Patents ADP number *(if you know it)*	34001	
6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number	Country	Priority application number *(if you know it)* / Date of filing *(day/month/year)*
7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application	Number of earlier application	Date of filing *(day/month/year)*
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11. I/We request the grant of a patent on the basis of this application

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Date 16 October 2000

12. Name and daytime telephone number of person to contact in the United Kingdom

Mr. C.I. Vigars [0117] 9103200

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COMMUNICATIONS SYSTEMS

The present invention relates to communications systems, and, in particular, to digital communications systems.

BACKGROUND OF THE INVENTION

Typical current digital communication systems often use non-constant envelope modulation schemes, e.g. the new system EDGE using $3\pi/8$-8PSK modulation. This means that some part of the information lies in the amplitude (envelope) of the transmitted signal and some part lies in the phase of the transmitted signal. In other words, this is a combination of Amplitude Modulation (AM) and Phase Modulation (PM).

To deal with amplitude modulation, an output Power Amplifier (PA) in the radio transmitter has to be linear, i.e. the relationship between the output power of the PA ($P_{out,PA}$) and the input power of the PA ($P_{in,PA}$) has to be linear for all possible power levels. Otherwise the result will be AM-to-AM distortion, i.e. the gain of the PA changes with the input amplitude.

To deal with the phase modulation, the phase-shift ($\Delta\phi$) through the PA has to be constant for all possible power levels. Otherwise the result will be AM-to-PM distortion, i.e. the phase-shift of the PA changes with the input amplitude.

The consequences of using a PA with non-constant gain and/or non-constant phase-shift, will be amplitude distortion and/or phase distortion in the transmitted signal. This distortion leads to spectrum broadening, which results in an increased adjacent channel disturbance. The amplitude/phase distortion (vector distortion) in the transmitter also affects the

performance of the communications system. For example, an increased BER (Bit Error Rate) in the communication system, will lead to a decreased signal quality (e.g. degraded audio quality in a voice application).

Therefore, linearity is crucial for a transmitter used in a digital modulation system with non-constant amplitude modulation. Moreover, high linearity requirements often lead to poor power efficiency. To attain good linearity and good power efficiency, some linearization method and/or some efficiency enhancement method are often used. A problem that often arises is then poor time alignment between the "information parameters" (or "information components"), i.e. gain and phase (polar representation), alternatively I and Q (cartesian representation).

There are several known ways to attain linearity and/or power efficiency in RF (Radio Frequency) transmitters for digital modulation systems with non-constant amplitude modulation, for example:

- Polar Loop Feedback
- Cartesian Loop Feedback
- Predistortion
- Adaptive Baseband Predistortion
- Feed-forward
- Envelope Elimination and Restoration
- Combining two power amplifiers

The methods can be divided in three categories:

1) How the modulation is generated:
   - Cartesian modulation, i.e. in-phase (I) and quadrature (Q)
   - Polar modulation (e.g. Envelope Elimination and Restoration), i.e. the signal is divided

into amplitude information (r) and phase information (ϕ)

2) Whether or not the method uses feedback

- Examples of methods using feedback: Polar loop feedback, Cartesian loop feedback, Adaptive baseband predistortion
- Examples of methods not using feedback: Predistortion, Feedforward, Envelope elimination and restoration, combination of 2 non-linear signals paths (e.g. LINC or CALLUM). For example, see DC Cox, "Linear amplification with non-linear components", IEEE Transactions on Communications, Vol 22, No. 12, pp 1942-1945, Dec 1974; and A. Bateman, "The combined analogue locked loop universal modulator (Callum), proceedings of the 42nd IEEE Vehicular Technical Conference, May 1992, pp 759-764.

3) How the feedback signal path, if any, is implemented

- I/Q-demodulator (I/Q-feedback),
- Amplitude feedback only
- Phase feedback only
- Both amplitude and phase-feedback

SUMMARY OF THE PRESENT INVENTION

One embodiment of the present invention can compensate for time delay between amplitude and phase-information. Alternatively, compensation for time delay between the in-phase component (I) and the quadrature component (Q) can be obtained. The timing problem is transferred to the digital baseband domain, where it can be solved. The method could be used in different linearization configurations, such as

"Cartesian Feedback", "Polar Loop Feedback" and "Envelope Elimination and Restoration with Linearization". Since the time delay compensation as well as the adaptive linearization takes place in the digital baseband domain, the invention is a form of "Adaptive Time-alignment of Information Components". As will be shown, the invention also gives increased flexibility in the choice of circuit configuration in the feedback part of the linearizer.

The invention can be applied both in TDMA (Time Division Multiple Access) systems or in CDMA (Code Division Multiple Access) systems. An example of a system in a TDMA category is EDGE (Enhanced Data rates for GSM Evolution). In the CDMA category we have, for example, Wideband CDMA or UMTS.

The invention presented in this report reduces time miss-alignment between the amplitude and the phase-information, alternatively between I and Q, in a radio transmitter. The invention can be applied in TDMA (Time Division Multiple Access) systems, or in CDMA (Code Division Multiple Access) systems. An example of a system in the TDMA category is EDGE (Enhanced Data rates for GSM Evolution), another is UMTS. In the CDMA category we have for example W-CDMA.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 illustrates a first embodiment of the present invention;

Figure 2 illustrates a second embodiment of the present invention;

Figures 3 and 4 illustrate respective output detector units suitable for use with the embodiments shown in Figures 1 and 2;

Figure 5 illustrates a third embodiment of the

present invention;

Figure 6 illustrates a fourth embodiment of the present invention ; and

Figure 7 illustrates an output detector unit suitable for use in the embodiments of Figures 5 and 6.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

A block diagram illustrating a first embodiment of the invention with compensation for time delay between the phase ϕ and the amplitude (envelope) r, is presented in Figure 1.

The system of Figure 1 includes a radio frequency transmitter having RF circuitry 1 including a power amplifier which produces a power amplifier output PA_{out} for supply to an antenna 2. The RF circuitry 1 receives phase and amplitude signals ($\phi 2$, r2) from which the output signal is produced. The operation of the RF circuitry is well known and will not be described in further detail for the sake of clarity.

In an embodiment of the present invention, an output detector unit 3 is provided which serves to monitor the power amplifier output signal and to produce detected phase and amplitude ($\phi 4$, r4) signals. A local oscillator (LO) 5 is provided in order to enable the output detector unit 3 to convert the RF power amplifier output signal to the digital baseband frequency of the circuit. The RF signal is mixed down to the digital baseband frequency. This operation can be performed by a mixer having one input from the RF signal and another input from the local oscillator 5. The mixer multiplies the two signals to produce a signal having one component having a frequency equal to the local oscillator frequency plus the RF frequency, and another component having a frequency equal to the

present invention;

Figure 6 illustrates a fourth embodiment of the present invention ; and

Figure 7 illustrates an output detector unit suitable for use in the embodiments of Figures 5 and 6.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

A block diagram illustrating a first embodiment of the invention with compensation for time delay between the phase ϕ and the amplitude (envelope) r, is presented in Figure 1.

The system of Figure 1 includes a radio frequency transmitter having RF circuitry 1 including a power amplifier which produces a power amplifier output PA_{out} for supply to an antenna 2. The RF circuitry 1 receives phase and amplitude signals (ϕ2, r2) from which the output signal is produced. The operation of the RF circuitry is well known and will not be described in further detail for the sake of clarity.

In an embodiment of the present invention, an output detector unit 3 is provided which serves to monitor the power amplifier output signal and to produce detected phase and amplitude (ϕ4, r4) signals. A local oscillator (LO) 5 is provided in order to enable the output detector unit 3 to convert the RF power amplifier output signal to the digital baseband frequency of the circuit. The RF signal is mixed down to the digital baseband frequency. This operation can be performed by a mixer having one input from the RF signal and another input from the local oscillator 5. The mixer multiplies the two signals to produce a signal having one component having a frequency equal to the local oscillator frequency plus the RF frequency, and another component having a frequency equal to the

difference in LO and RF frequencies. The LO+RF frequency is filtered out, leaving a baseband frequency signal. The system also incorporates a signal generator 7 which receives digital data D and operates to produce phase and amplitude information (ϕ_1, r_1) for supply to the RF circuitry 1.

In an embodiment of the present invention, the phase information (ϕ_1) produced by the signal generator 7 is supplied to a delay element 8_1. The delay element 8_1 operates to delay the signal ϕ_1 by an amount of time controlled by a controller 9_1. The output of the delay unit 8_1 (i.e. a delayed ϕ_1) is subtracted by a combining unit 10_1 from the detected phase signal (ϕ_4) of the output detector unit 3. The delay controller 9_1 operates to modify the delay introduced by the delay unit 8_1 such that the magnitude of the difference between the detected phase value (ϕ_4) and the delayed generated phase value (ϕ_3) is minimised. The result of this control, signal d_1 is a measurement of how much the phase signal ϕ is delayed in the RF circuitry 1.

Corresponding circuit elements are provided for the generated amplitude signal r_1. The amplitude signal r_1 is delayed by a delay unit 8_2 which is itself controlled by a delay controller 9_2. A combining unit 10_2 subtracts the delayed generated amplitude signal r_3 from the detected amplitude signal r_4. The delay controller 9_2 operates to minimize the magnitude of the difference between the detected and delayed generated amplitude signals (r_4, r_3). As before, the delay control signal d_2 for the amplitude circuit is a measurement of how much the amplitude signal r is delayed by the RF circuitry 1.

An embodiment of the present invention includes a delay calculation unit 12 which receives the outputs from the delay control units 9_1 and 9_2 (signals d_1 and

d_2). The delay calculation unit 12 determines the difference between the two input signals and produces control outputs $d\phi$ control and dr control. The control outputs $d\phi$, dr from the calculation unit 12 are used as inputs to a phase controller 14 and an amplitude controller 16 respectively. The phase controller 14 operates to adjust the generated phase signal ϕ_1 for supply (ϕ_2) to the RF power amplifier circuitry, and the amplitude controller 16 operates to adjust the generated amplitude signal r_1 for supply (r_2) to the power amplifier circuitry. The phase and amplitude controllers 14 and 16 operate to compensate for the actual detected time delay between the phase and the amplitude detected by the output detector unit 3.

Figure 2 describes another embodiment of the invention. The difference between Figure 1 and Figure 2 is that the latter shows a system where the input signals to the RF circuitry 1 are in-phase (I) and quadrature (Q) signals. A polar to Cartesian converter 17 is therefore needed to convert the amplitude (r) and phase (ϕ) information polar into an in-phase component (I) and a quadrature component (Q). The relationship between I, Q, ϕ and r is given by equation (1):

$$I + j \cdot Q = r \cdot e^{j \cdot \phi} \quad (1)$$

Figure 3 illustrates one configuration of an output detector unit 3 which is suitable for use in the system of Figures 1 and 2. The output detector unit 3 includes an I/Q demodulator 31 which uses the output of a local oscillator 5 to produce detected in-phase I and quadrature Q signals from the PA output signal. A cartesian to polar conversion unit 32 converts the detected in-phase (I) and quadrature (Q) signals to

detected amplitude (r) and phase (ϕ) signals.

Figure 4 illustrates an alternative output detector unit 3 for use in the systems of Figures 1 and 2. The output detector unit 3 of Figure 4 includes a signal limiter 33 and phase detector 35 which together operate to produce a detected phase signal (ϕ). An envelope detector 34 is provided which operates to Produce a detected amplitude signal (r).

Figure 5 illustrates a third embodiment of the present invention. This third embodiment is similar to the first and second embodiments, except that an output detector unit 18 is provided which operates to detect the in-phase component I and the quadrature component Q from the power amplifier output signal. The output detector unit 18 of Figure 5 supplies the detected I and Q components to the remainder of the system. A signal generator 20 is provided that receives digital data D and produces in-phase I and quadrature Q signals for supply to the RF circuitry 1. The generated I and Q signals are delayed and subtracted from the detected I and Q signals, in a manner similar to that described with reference to Figures 1 and 2. Delay of the generated I signal is controlled by a control 9_1 such that the difference between detected and delayed generated signals is minimised. The delay of the generated Q signal is controlled by a control 9_2 such that the difference between the detected Q signal and delayed generated Q signal is minimised. The control signals that are produced by the controls 9_1 and 9_2 to control delay elements 8_1 and 8_2 are respective measurements of how each component is delayed by the RF circuitry 1. As before, a delay calculation circuit 12 is provided, and operates to produce I and Q control signals $d_{ICONTROL}$, $d_{QCONTROL}$ from the delay control signals. I and Q controllers 22 and 24 respectively operate to

adjust the generated I and Q values on the basis of the determined delay values. Thus, the corrected I and Q values are compensated for actual time delay between the in-phase component and the quadrature component produced by action of the RF circuitry 1.

Figure 6 describes a fourth embodiment of the present invention. The difference between Figure 5 and Figure 6 is that the latter describes a system in which the input signals to the RF circuitry are phase and amplitude signals(i.e. polar signals). An extra block, a Cartesian to polar converter 25, is therefore needed to convert the in-phase component (I) and one quadrature component (Q) into amplitude (r) and phase (ϕ) information. The relation between I, Q, ϕ and r is, as mentioned earlier, is given by equation (1).

In the following, x and y are used to represent parameters that, from the above-described embodiments would be a polar or cartesian parameter. The block Delay 1 Control 9_1 changes the delay control parameter d_1 (i.e. the delay value of Delay unit 8_1) until the difference Δ_x between x_3 and x_4 has been minimised. The difference between x_3 and x_4 could <u>for example</u> (however other possibilities exist) be calculated as the "Least-Mean-Square"-value (LMS) given by equation (2):

$$\Delta_x = \sum_{k=n}^{n+m} \left(x_1(k + d_1) - x_4(k) \right)^2 \qquad (2)$$

where m is the number of samples over which the LMS-value is calculated. The value d_1 is the number of samples which x_1 is delayed in order to form x_4. When min $\{\Delta_x\}$ has been found, the "final" value of d_1 has also been found.

In the same way, delay control 9_2 changes the delay

parameter d_2 (i.e. the control delay value of delay unit 8_2) until the difference Δ_y between y_3 and y_4 has been minimised. This means that d_2 is obtained by minimising Δ_y in the expression (equation (3)):

$$\Delta_y = \sum_{k=n}^{n+m} \left(y_1\left(k + d_2\right) - y_4(k) \right)^2 \qquad (3)$$

After d_1 and d_2 have been found, we can calculate dx and dy, which are the two parameters used for achieving time-alignment between x and y. Since d1 and d2 tell us how much the signals x respectively y are delayed in the system, the time delay between x and y can be found by calculating $\Delta_{xy}=d_1-d_2$. If $\Delta_{xy}>0$, i.e. if $d_1>d_2$, then x_2 should be sent Δ_{xy} samples before y2. Use for example $d_x=0$ and $d_y=\Delta_{xy}$.

Correspondingly, if $\Delta_{xy}<0$, i.e. if $d_1<d_2$, then x_2 should be sent Δ_{xy} samples after y_2. Use for example $d_x=\Delta_{xy}$ and $d_y=0$.

If $\Delta_{xy}=0$, no correction is needed. Use for example $d_x=d_y=0$.

Benefits of embodiments of the invention are listed below:

- Automatic compensation of parameter variations in the transmitter, since the time-delay compensation is adaptive. For the same reason, the solution is able to compensate for temperature variations.
- Flexibility, since there are several possible transmitter configurations, in which the invention can work.
- Embodiments of the invention could also be used together with linearization schemes, for example

with adaptive predistortion linearization. The linearization will perform better if time-alignment between ϕ and r (alternative I and Q) is made prior to calculation of the predistorted ϕ-value and r-value (alternative I-value and Q-value).

As mentioned, embodiments of the invention can be very flexible. It could be used in several types of system:

1) Systems with different types of modulation principles

- Polar modulation (e.g. "Envelope Elimination and Restoration", systems with polar feedback loop, etc.)
- Cartesian modulation (e.g. systems with cartesian feedback loop)
- Modulation with non-linear PA's (e.g. LINC, CALLUM, etc).

2) Systems with different types of feedback

- polar feedback
    - Both amplitude and phase detection
    - Amplitude detection only
    - Phase detection only
- Cartesian feedback (i.e. quadrature demodulator in the feedback loop)

CLAIMS:

1. A method of adjusting a radio frequency signal produced by radio frequency circuitry in response to receipt of phase and amplitude control signals from digital baseband circuitry which operates to convert digital data signals into such phase and amplitude control signals, wherein the phase and amplitude control signals are adjusted in the digital baseband circuitry in order to compensate for time alignment errors which occur in the radio frequency circuitry.

2. A method as claimed in claim 1, wherein the time alignment errors in the radio frequency signal are detected by comparing phase and amplitude components of the radio frequency signal with phase and amplitude control signals produced by the digital baseband circuitry.

3. A method as claimed in claim 2, wherein the phase and amplitude control signals are adjusted in dependence upon the comparison of phase and amplitude components of the radio frequency signal with phase and amplitude control signals produced by the digital baseband circuitry.

4. A method of adjusting timing of amplitude and phase components in an output RF signal, the method comprising:

generating amplitude and phase signals from input data;

adjusting the generated amplitude and phase signals to produce adjusted amplitude and phase signals;

supplying the adjusted amplitude and phase signals to a radio frequency circuit; and

transmitting an output RF signal from the radio frequency circuit, wherein adjusting the generated amplitude and phase signals comprises:

detecting an output RF signal to produce detected amplitude and phase signals;

subjecting the generated phase signal to a first time delay to produce a delayed phase signal, the first time delay being such as to minimise a difference between the delayed phase signal and the detected phase signal;

subjecting the generated amplitude signal to a second time delay to produce a delayed amplitude signal, the second time delay being such as to minimise the difference between the delayed amplitude signal and the detected amplitude signal; and

adjusting the generated amplitude and phase signals in dependence upon the first and second time delays.

5. A method as claimed in claim 4, wherein the adjusted amplitude and phase signals are converted to inphase and quadrature (I and Q) signals for supply to the radio frequency circuit.

6. A method of adjusting a radio frequency signal produced by radio frequency circuitry in response to receipt of inphase and quadrature (I and Q) control signals from digital baseband circuitry which operates to convert digital data signals into such inphase and quadrature (I and Q) control signals, wherein the inphase and quadrature (I and Q) control signals are adjusted in the digital baseband circuitry in order to compensate for time alignment errors which

occur in the radio frequency circuitry.

7. A method as claimed in claim 6, wherein the time alignment errors in the radio frequency signal are detected by comparing inphase and quadrature (I and Q) components of the radio frequency signal with inphase and quadrature (I and Q) control signals produced by the digital baseband circuitry.

8. A method as claimed in claim 7, wherein the inphase and quadrature (I and Q) control signals are adjusted in dependence upon the comparison of inphase and quadrature (I and Q) components of the radio frequency signal with inphase and quadrature (I and Q) control signals produced by the digital baseband circuitry.

9. A method of adjusting timing of inphase and quadrature (I and Q) components in an output RF signal, the method comprising:

generating inphase and quadrature (I and Q) signals from input data;

adjusting the generated inphase and quadrature (I and Q) to produce adjusted inphase and quadrature (I and Q) signals;

supplying the adjusted inphase and quadrature (I and Q) signals to a radio frequency circuit; and

transmitting an output RF signal from the radio frequency circuit, wherein adjusting the generated inphase and quadrature (I and Q) signals comprises:

detecting an output RF signal to produce detected inphase and quadrature (I and Q) signals;

subjecting the generated inphase (I) signal to a first time delay to produce a delayed inphase (I) signal, the first time delay being such as to minimise

a difference between the delayed inphase (I) signal and the detected inphase (I) signal;

subjecting the generated quadrature (Q) signal to a second time delay to produce a delayed quadrature (Q) signal, the second time delay being such as to minimise the difference between the delayed quadrature (Q) signal and the detected quadrature (Q) signal; and

adjusting the generated inphase and quadrature (I and Q) signals in dependence upon the first and second time delays.

10. A method as claimed in claim 9, wherein the adjusted inphase and quadrature (I and Q) signals are converted to phase and amplitude signals for supply to the radio frequency circuit.

11. A radio frequency transmitter which includes digital baseband circuitry operable to produce phase and amplitude control signals at a first frequency from input digital data signals, the transmitter also including radio frequency circuitry operable to output radio frequency signals in dependence upon phase and amplitude control signals or upon inphase and quadrature (I and Q) signals received from the digital baseband circuitry, wherein the digital baseband circuitry is operable to correct the phase and amplitude control signals for time alignment errors that occur in the radio frequency circuitry.

12. A transmitter as claimed in claim 11, wherein the digital baseband circuitry includes means for comparing phase and amplitude components of an RF signal with delayed phase and amplitude control signals, and is operable to adjust the phase and amplitude control signals in dependence upon the result

of the comparison.

13. Apparatus for adjusting timing of phase and amplitude components of an RF signal, the apparatus comprising:

an RF detector unit for detecting an RF signal and operable to produce detected phase and amplitude signals therefrom;

an adjustment unit connected to receive generated phase and amplitude signals and operable to output adjusted phase and amplitude signals in dependence upon received adjustment control signals;

a delay unit connected to receive the generated phase and amplitude signals and operable to delay those signals by respective time delays to produce delayed phase and amplitude signals, the respective time delays being determined such that respective differences between detected and delayed phase and amplitude signals are minimised; and

a delay calculation unit which is operable to generate adjustment control signals in dependence upon the respective time delays and to supply the adjustment control signals in dependence upon respective time delays and to supply the adjustment control signals to the adjustment unit.

14. A radio frequency transmitter which includes digital baseband circuitry operable to produce inphase and quadrature (I and Q) control signals at a first frequency from input digital data signals, the transmitter also including radio frequency circuitry operable to output radio frequency signals in dependence upon inphase and quadrature (I and Q) control signals or upon amplitude and phase signals received from the digital baseband circuitry, wherein

the digital baseband circuitry is operable to correct the inphase and quadrature (I and Q) control signals for time alignment errors that occur in the radio frequency circuitry.

15. A transmitter as claimed in claim 14, wherein the digital baseband circuitry includes means for comparing inphase and quadrature (I and Q) components of an RF signal with delayed inphase and quadrature (I and Q) control signals, and is operable to adjust the inphase and quadrature (I and Q) control signals in dependence upon the result of the comparison.

16. Apparatus for adjusting timing of inphase and quadrature (I and Q) components of an RF signal, the apparatus comprising:

an RF detector unit for detecting an RF signal and operable to produce detected inphase and quadrature (I and Q) signals therefrom;

an adjustment unit connected to receive generated inphase and quadrature (I and Q) signals and operable to output adjusted inphase and quadrature (I and Q) signals in dependence upon received adjustment control signals;

a delay unit connected to receive the generated inphase and quadrature (I and Q) signals and operable to delay those signals by respective time delays to produce delayed inphase and quadrature (I and Q) signals, the respective time delays being determined such that respective differences between detected and delayed inphase and quadrature (I and Q) signals are minimised; and

a delay calculation unit which is operable to generate adjustment control signals in dependence upon the respective time delays and to supply the adjustment

control signals in dependence upon respective time delays and to supply the adjustment control signals to the adjustment unit.

17. A method of controlling radio frequency circuitry in a mobile telecommunications device comprising a method as claimed in any one of claims 1 to 10.

18. A mobile telecommunications device comprising a radio frequency transmitter as claimed in any one of claims 11, 12, 14 and 15.

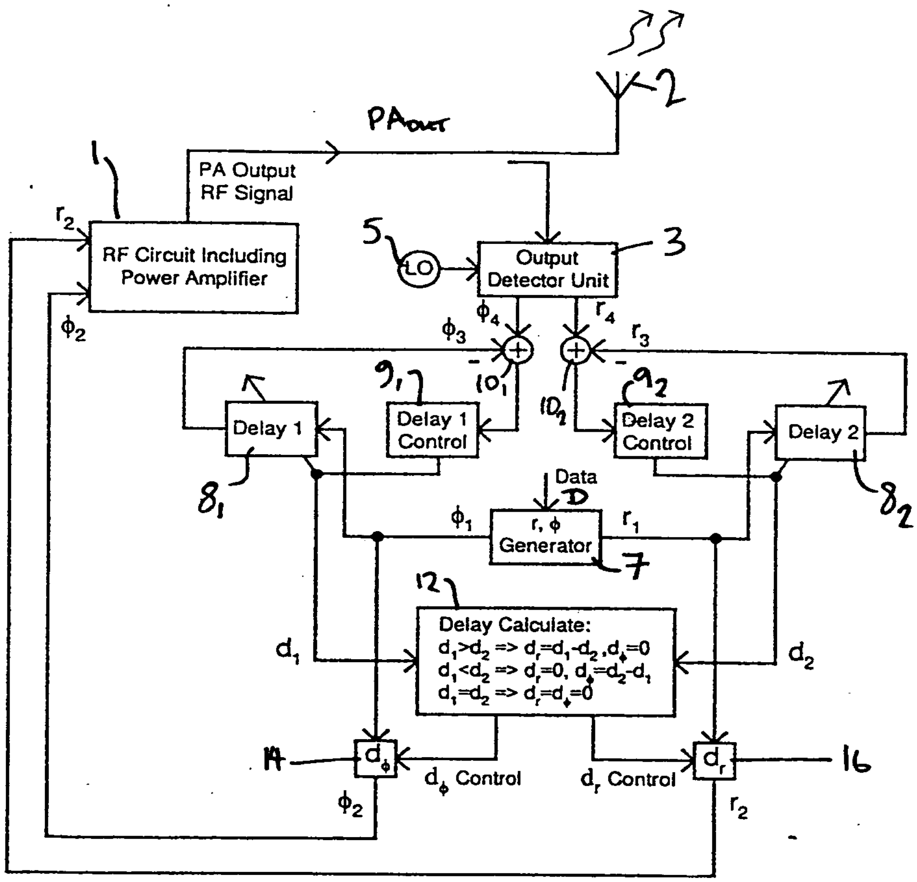
19. A mobile telecommunications device comprising radio frequency circuitry and apparatus as claimed in claim 13 or 16.

ABSTRACT

COMMUNICATIONS SYSTEMS

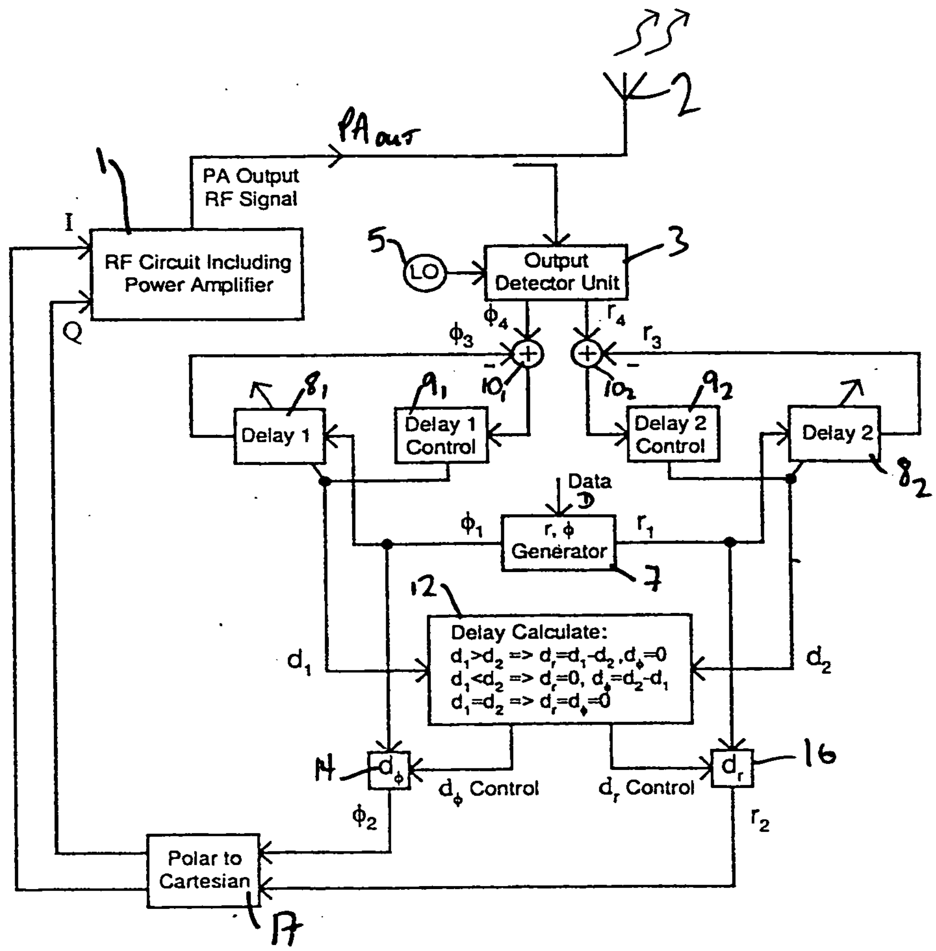
The invention relates to a method of adjusting a radio frequency signal produced by radio frequency circuitry in response to receipt of phase and amplitude control signals from digital baseband circuitry which operates to convert digital data signals into such phase and amplitude control signals. The phase and amplitude control signals are adjusted in the digital baseband circuitry in order to compensate for time alignment errors which occur in the radio frequency circuitry.

[Fig 1]



PA$_{OUT}$
2
1
PA Output RF Signal
RF Circuit Including Power Amplifier
5
LO
Output Detector Unit
3
r_2
ϕ_2
ϕ_4
r_4
ϕ_3
r_3
10_1
10_2
9_1
9_2
Delay 1
Delay 1 Control
Delay 2 Control
Delay 2
8_1
8_2
Data
D
ϕ_1
r_1
r, ϕ Generator
7
12
Delay Calculate:
$d_1>d_2 \Rightarrow d_r=d_1-d_2, d_\phi=0$
$d_1<d_2 \Rightarrow d_r=0, d_\phi=d_2-d_1$
$d_1=d_2 \Rightarrow d_r=d_\phi=0$
d_1
d_2
14
d_ϕ
d_ϕ Control
d_r Control
d_r
16
ϕ_2
r_2

FIGURE 1



PA out
2
1
PA Output
RF Signal
I
RF Circuit Including Power Amplifier
Q
5
LO
Output Detector Unit
3
ϕ_4
r_4
ϕ_3
r_3
10_1
10_2
8_1
9_1
9_2
Delay 1
Delay 1 Control
Delay 2 Control
Delay 2
8_2
Data
D
ϕ_1
r, ϕ Generator
r_1
7
12
Delay Calculate:
$d_1>d_2 \Rightarrow d_r=d_1-d_2, d_\phi=0$
$d_1<d_2 \Rightarrow d_r=0, d_\phi=d_2-d_1$
$d_1=d_2 \Rightarrow d_r=d_\phi=0$
d_1
d_2
14
d_ϕ
d_ϕ Control
d_r Control
d_r
16
ϕ_2
r_2
Polar to Cartesian
17

FIGURE 2

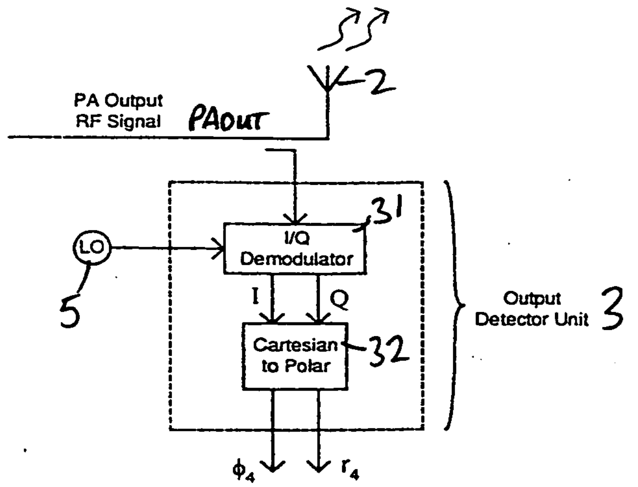


FIGURE 3

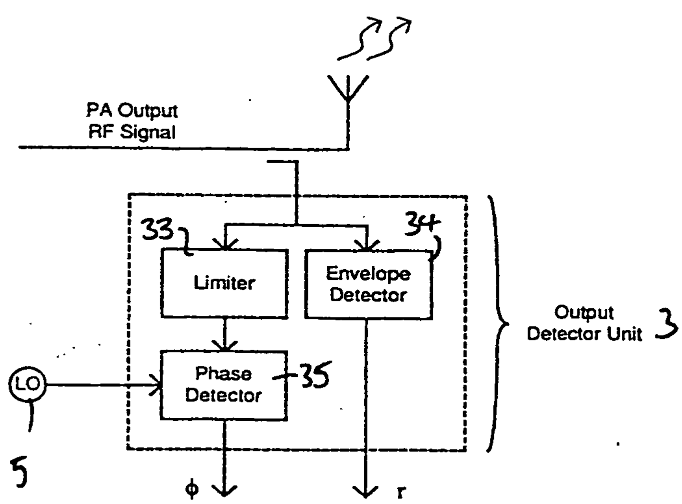


FIGURE 4

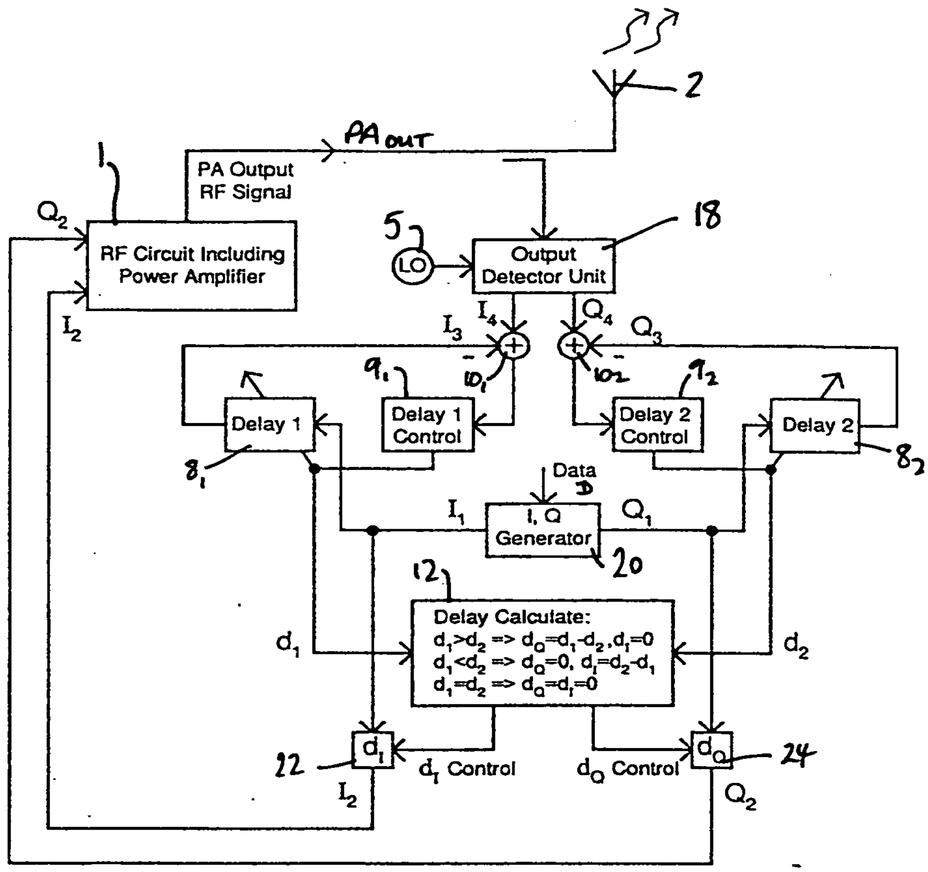

2
PA OUT
1
PA Output RF Signal
Q2
RF Circuit Including Power Amplifier
I2
5
LO
Output Detector Unit
18
I4
Q4
I3
Q3
9_1
10_1
10_2
9_2
Delay 1
Delay 1 Control
Delay 2 Control
Delay 2
8_1
8_2
Data
D
I1
I, Q Generator
Q1
20
12
Delay Calculate:
d1>d2 => dQ=d1-d2, dI=0
d1<d2 => dQ=0, dI=d2-d1
d1=d2 => dQ=dI=0
d1
d2
22
dI
dI Control
dQ Control
dQ
24
I2
Q2

FIGURE 5

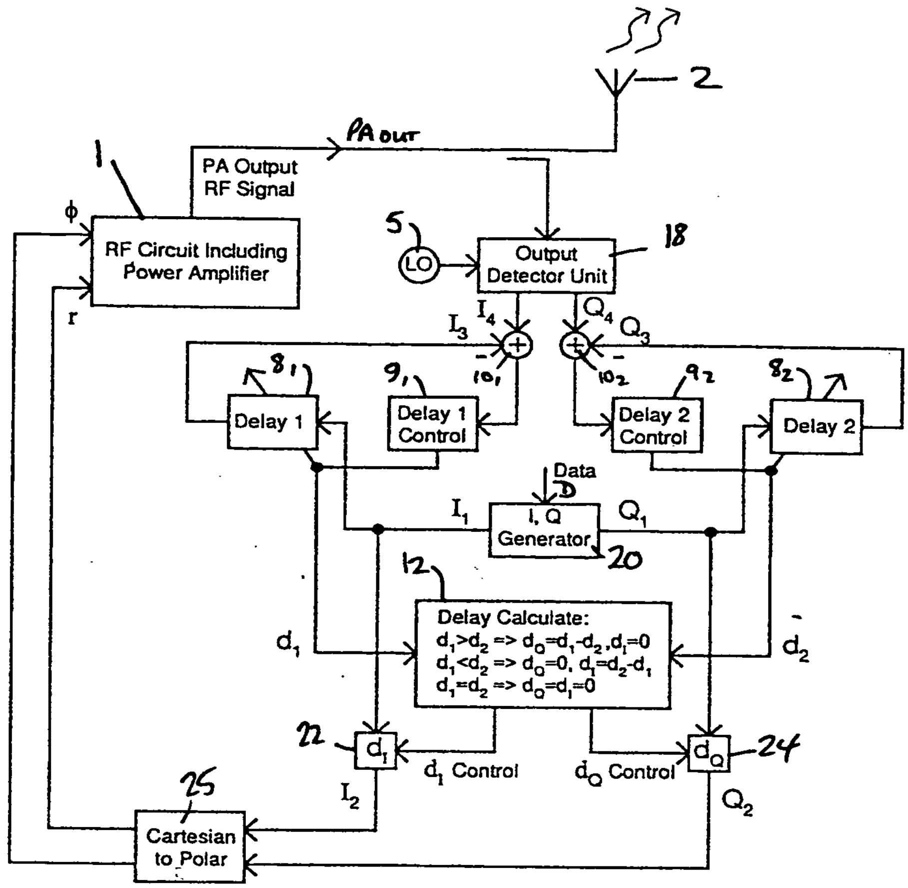


FIGURE 6

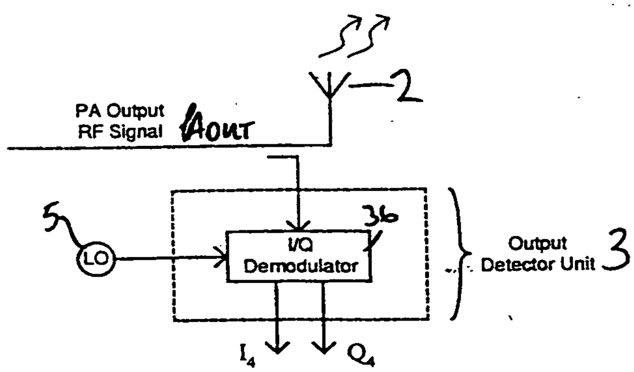


FIGURE 7